

Nuclear Science Program at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU)

Overview

The National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University is the premier intermediate-energy heavy-ion user facility on the North American continent. Since its inception, the NSCL has played a significant role in nuclear and accelerator physics research, both in the U.S. and worldwide. This role will continue at an enhanced level with the coupled cyclotron upgrade now nearing completion. In the 1996 Long Range Plan of the NSF/DOE Nuclear Science Advisory Committee, this upgrade project was recommended to be the highest priority for new construction. The new Coupled Cyclotron Facility (CCF) is on track to be operational, as originally proposed, by July 1, 2001.

The intensity gains of intermediate-energy primary heavy-ion beams made possible with the coupled cyclotron operation and the increased acceptance of the new A1900 fragment separator will permit the production of fast beams of rare isotopes typically more intense by factors of 100 – 10,000 than available at the previous K1200/A1200 facility. A gas cell for stopping and delivering rare isotopes to a 9.4 T Penning ion trap for precision mass measurements is under construction. Until the completion of the Rare Isotope Accelerator (RIA) now under discussion, the CCF will offer opportunities unique in the US to develop and test many of the experimental, theoretical and technical concepts pertinent for a successful program at RIA. After the eventual completion of RIA, the CCF will remain a particularly cost-effective option for research with lighter nuclides ($A < 100$).

The projected scientific reach of the CCF, illustrated in Fig. 1, positions the NSCL well for a continued strong leadership role in research with rare isotopes with a focus in three major areas of high scientific interest:

- The exploration of nuclei with unusual ratios of protons to neutrons and the determination of their properties.
- The exploration of the nuclear processes that occur in explosive stellar environments and that are responsible for the ongoing synthesis of the elements in the cosmos.
- The exploration of isospin dependent properties of hot nuclear matter at sub- and supra-normal densities.

Facility Description

The floor plan of the high bay experimental area is shown in Fig. 2. The accelerator facility has the capability of ionizing essentially any chemical element and accelerating those ions to energies of approximately 10 - 200 MeV/nucleon (the exact energy range depends on the A/Z ratio of the isotope). These energetic primary beams can be used directly, or they can be converted into a broad range of radioactive ions that are

separated in-flight (by means of the new high-acceptance A1900 fragment separator) and delivered to one of six experimental vaults. Change-over capability to the original stand-alone operation of the K1200 has been preserved. Several equipment items were constructed by or with the help of outside users. The availability of all equipment items to all users is an integral part of the proposed facility operation.

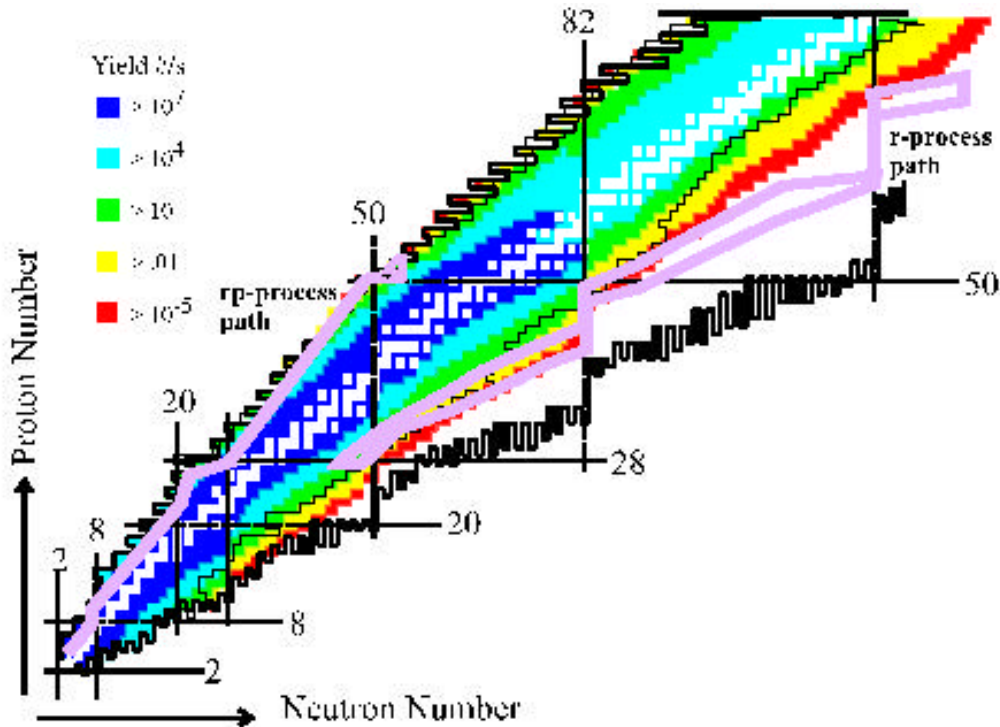


Figure 1: The scientific reach of the NSCL Coupled Cyclotron Facility is illustrated in terms of the projected intensities for fast beams of rare isotopes. Note of caution: Far from stability, the predicted intensities become increasingly uncertain due to a current lack of experimental data. (A color version of this plot can be found at the NSCL website: <http://www.nsl.msui.edu/research/ribeams/home.html>.)

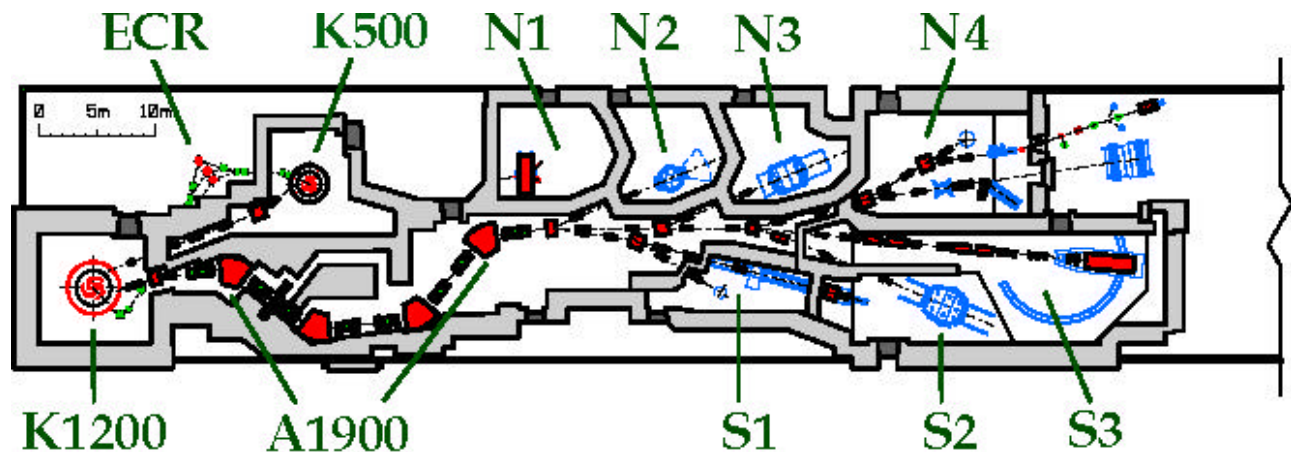


Figure 2: Floor plan of the NSCL high bay experimental area showing the two superconducting cyclotrons (K500 and K1200 on the left), the superconducting A1900 beam analysis system and subsequent beamlines, the various experimental vaults, and the newly constructed areas.

Existing equipment items include the large 4 -Array (N2), 92-inch chamber (N3), S800 magnetic spectrograph (S3), Superball neutron multiplicity meter (S2), RPMS Wien

Filter (S1), and several portable large-solid-angle detectors Miniball, Neutron Walls, NaI array. A new beamline for the investigation of single electron events (SEE) in computer chips is being funded by NASA and will be available to users. Major new equipment under construction includes a segmented germanium array, a highly granular Si-strip-CsI array, and a sweeper magnet (all funded by NSF as MRI's); a gas cell for stopping rare isotopes (funded by DOE), and a Penning ion trap (funded by MSU). A new proposal for a high-energy neutron-wall is in preparation. R&D for a low-energy re-accelerator is in the exploration stage.

Statistical Information

From January 1996 until the scheduled shutdown on July 1, 1999, the K1200 cyclotron delivered beam for a total of 17,126 hours, corresponding to an average rate of 4893 hours/year. The experiments were performed by approximately 375 scientists (80 from the NSCL, 172 from elsewhere in the U.S., and 123 from abroad) from 81 institutions in 22 countries. Consistent with the important educational mission of the NSCL, 90 students (38 from MSU and 52 from other institutions) participated in these experiments. Approximately three-quarters of the experiments required secondary beams.

The present NSCL staff includes 23 faculty, 43 Ph.D.s, 85 technical/administrative staff, 14 postdocs, 40 graduate students, and 53 undergraduate students.

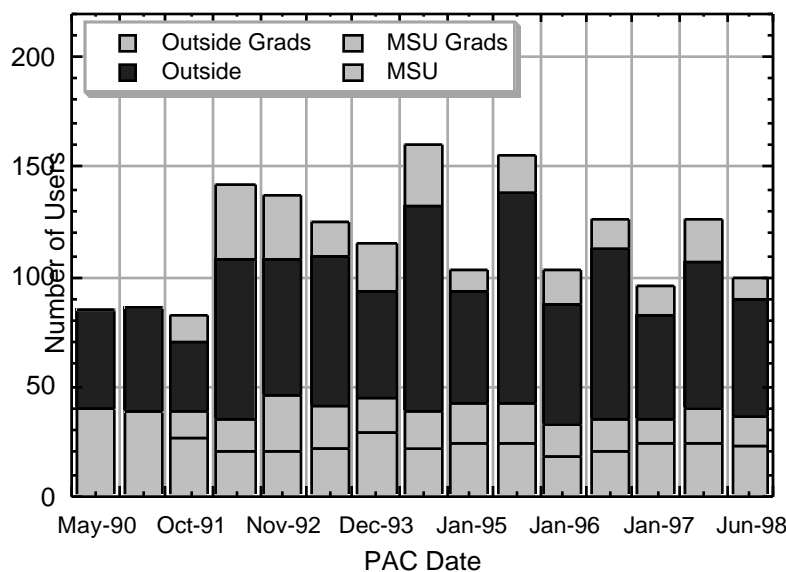


Figure 2: Historical user statistics for PAC approved experiments.

In view of the impending resumption of operations, a new NSCL CCF user group consisting of more than 400 users was formed. Actual use of the CCF is likely to be similar to that of the past. The historical number of users that were actually granted beam time at various PAC meetings is shown in Fig. 3. Virtually all of these experiments have received the requested beam time. Because of the CCF-construction related shutdown of the experimental program no full-year user statistics is available

for 1999 and 2000. The average number of users for the years 1997 and 1998 was 183/y: Ph.D. (70%), G.S. (28%), Other (2%); with funding from: DOE (18%), NSF (46%), Other US (10%), Foreign (26%).

Educational Impact

Located on the campus of a major research university, the NSCL provides a unique research and teaching environment that optimally combines academic studies with hands-on training for students and an integrated approach to reaching out to the general public, to teachers, and to pre-college students.

The NSCL plays a major role in training the next generation of nuclear scientists for the United States. Typically, in a given year more than 60 graduate students from MSU and other universities work at the NSCL on Ph.D. programs in experimental or theoretical nuclear physics, nuclear astrophysics, nuclear chemistry, or accelerator physics. More than ten postdoctoral research associates reside at the NSCL, supported by funds from MSU, NSF, DOE, and foreign institutions.

For more than a decade, the NSCL has made available summer internships to talented undergraduate students via an NSF- and MSU-funded REU (Research Experience for Undergraduates) program, especially targeting students from underrepresented groups.

NSCL faculty have an excellent reputation for high-quality instruction and innovation in the classroom. Several NSCL faculty have received the prestigious Teacher Scholar Award. Faculty at the NSCL are using technology to implement active learning environments in large lecture courses commonly found at large research universities (CAPA, "virtual university"). NSCL faculty and a recent NSCL Ph.D. graduate received a \$2.1M NSF-ITR grant (LON-CAPA) for researching and further developing the use of information technology to enhance the learning experience of students.

Funding Needs

In order to run the coupled cyclotron facility as a user facility, the technical staff must be increased by about 13 FTE as compared to the staff level of FY1996 (6 FTE operators; 2 FTE for rare isotope preparation, beamline tuning and tracking; 1.5 FTE for cryoplant operation, 1.5 FTE for control systems support, 2 FTE for user support with complex experimental devices). In addition, we need a 2 FTE increase for graduate student and postdoc support.

The funds needed for efficient operation and in-house research starting from July 2001 are about 13 M\$ for FY 2001 and \$14.5 M for FY2002. Total external funding of the NSCL in FY2000 was \$15.3 M from NSF, \$1.1 M from DOE, and \$0.2 M from other sources. At the time of writing (January 24, 2001), the FY2001 (Nov. 1, 2000 – Oct 31, 2001) operating budget of the NSCL is unknown and the level of operations possible after construction of the CCF is uncertain.